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TEST PLANNING, COLLECTION, AND ANALYSIS OF PRESSURE DATA RESULT--ETC(U)

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TEST PLANNING, COLLECTION, AND ANALYSIS OF PRESSURE DATA RESULTING FROM ARMY WEAPON SYSTEMS.

~~Final Report~~

[redacted] I Pure Tone Audiograms for Minipigs.

William M. Jenkins
Henry C. Evans

Dec[redacted] 1979

Supported by

U.S. Army Medical Research and Development Command
Fort Detrick, Frederick, Maryland 21701

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The primary goal of this work was the development of a rapid, reliable and valid behavioral psychophysical technique for the assessment of pure tone audiograms in the minipig. The two-choice procedure was found to be better than the go-no-go procedure. The test apparatus was satisfactory with modifications and the minipig would be a suitable animal for studying high-peak pressure impulse-noise hearing loss.

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FOREWORD

JAYCOR has been assisting the Walter Reed Army Institute of Research (WRAIR) since September, 1978, in their Blast Overpressure Program. The major areas of assistance under Contract DAMD17-78-C-8087 have been the reduction and analysis of pressure-time data, modeling of the far field blast, development of test procedure and apparatus for pure tone audiograms of minipigs and logistical support for the Pilot Sheep Study. Additional tasks undertaken by JAYCOR at the request of WRAIR, were the development of a computer program for the tabulation of data from the Dog Study, assistance in necropsy during the Pilot Sheep Study, and clerical assistance of the gross anatomy sheep tapes.

As specific tasks are completed, reports will be compiled as deliverables. The following volumes will encompass the overall report:

- Volume I - Pure Tone Audiograms for Minipigs
- Volume II - Modeling of Far Field Data
- Volume III - Correlation Window Study M-198
- Volume IV - May 1979, M109 and M198 Data Analysis
- Volume V - Lovelace Data Analysis and Correlation Study

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SECTION 1

EXECUTIVE SUMMARY

1.1 BACKGROUND

JAYCOR was requested to develop a behavioral psychophysical technique for the assessment of pure tone audiograms for a minipig in conjunction with the efforts of the US Army Aeromedical Research Laboratory (USAARL), Ft. Rucker, Alabama. This task was performed by JAYCOR at USAARL under contractual arrangements already in existence with Walter Reed Army Institute for Research (WRAIR) (Contract No. DAMD17-78-C-8087). As no major efforts with pure tone audiograms for minipigs had previously been accomplished, it was a new area of research. This effort was prompted as a possible alternative for research in the Blast Overpressure Program of WRAIR. Since the US Army's XM198 Howitzer (155mm), as well as other weapon systems, produce peak pressures in the 180 dB range, it was deemed necessary to develop a large animal model capable of withstanding these high peak pressures.

Current animal models (chinchillas) can be used to investigate the effects of impulse noise that does not exceed 160 dB (re: .0002 dynes/cm^2). Beyond 160 dB, however, the chinchilla's tympanic membrane perforates. The minipig was selected because of its size (90-150 lbs), suspected similarity of its hearing to man, ease of its care and its reportedly high intelligence. Thus, the minipig might be an ideal large animal model for studying intense noise-induced hearing loss.

1.2 OBJECTIVE

The primary goal of this work was the development of a rapid, reliable and valid behavioral psychophysical technique for the assessment of pure tone audiograms in the minipig.

A large number of psychophysical techniques have been developed over the years (for a review see Stebbins, 1970), all of which may provide similar audiograms. The two-choice and go-no-go techniques have yielded reliable and valid results with less training and testing of the animals than many other methods. Furthermore, because the techniques have proven successful with a wide range of species (Burdick and Miller, 1973, 1975; Francis, 1975; Herman and Arbeit, 1973; Mohl, 1968; Terhune and Rowald, 1972; Heffner, Personnel Communication), our approach focused on these two procedures.

1.3 PROBLEM AREAS

Two major problem areas can be identified: 1) High thresholds; and 2) behavioral problems with the go-no-go technique. Possible reasons for the high thresholds will be enumerated first.

High Thresholds

1. Sound field was non-uniform; large variations (in excess of 15 dB) were seen for frequencies above 500 Hz.

2. Food reward resulted in masking noise due to mastication: long inter-trial intervals (25 seconds) were instituted to avoid some of the masking noise.

3. Animal produced masking noise other than mastication.

4. Ear wax buildup in the ear canal resulted in sound attenuation.

5. Minipigs were not young adults, but over four years of age and, therefore, may have had some natural decrease in hearing sensitivity.

6. The minipigs tested had a history of illness involving fever and drug treatment which may have had deleterious effects on their hearing.

Behavioral Problems

1. Symetric reward in the go-no-go procedure resulted in ambiguous situations for the animal and, therefore, was not an effective test procedure.

Note: No such procedural difficulties were encountered with the two-choice technique.

1.4 DISCUSSION

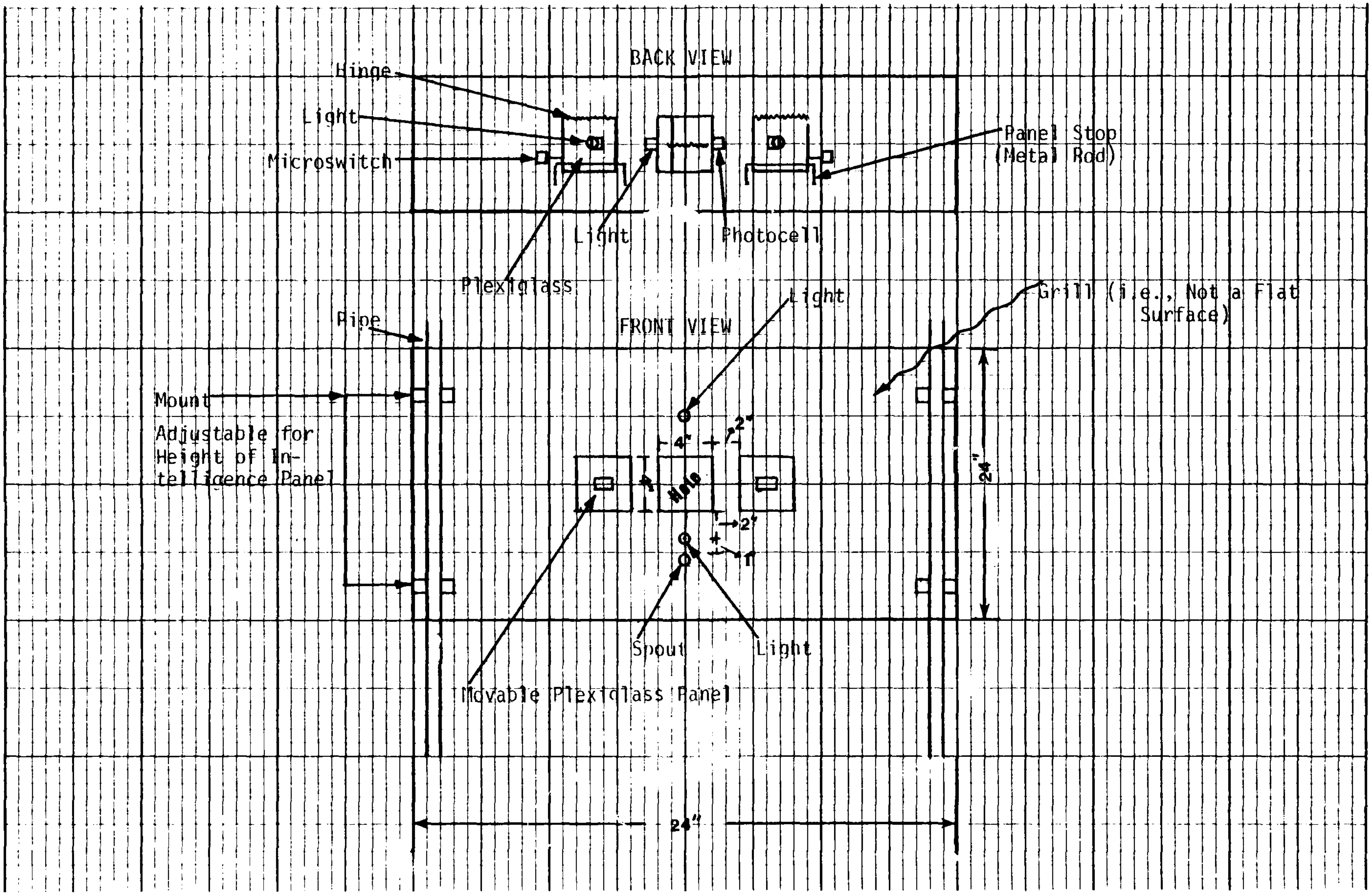
Minipigs appear to show promise as models for high-intensity impulse noise exposure. They learned the two-choice procedure with relative ease, and, in addition, following a two to three-day time period during which the pigs were not tested, they did not require additional training to establish high performance levels. This is important since noise exposure may last for a day or two. Thus, a shift in the hearing threshold could be attributed to the noise exposure and not merely to a break in the training and testing schedule.

It is evident from the previous section on problems that corrective measures will need to be instituted before the minipig can be used as a model for studying noise-induced hearing loss. These changes will be addressed in the following section.

1.5 RECOMMENDATIONS

1. To redesign the intelligence panel so that flat reflective surfaces are minimized (see Figure 1-1).

2. To switch to a liquid reward system which uses a solenoid valve. This would eliminate most, if not all, of the mastication noise and would allow the inter-trial interval to be reduced. Thus, a greater number of test trials could be obtained in less time (see Figure 1-2).



Intelligence Panel. Figure 1-1.

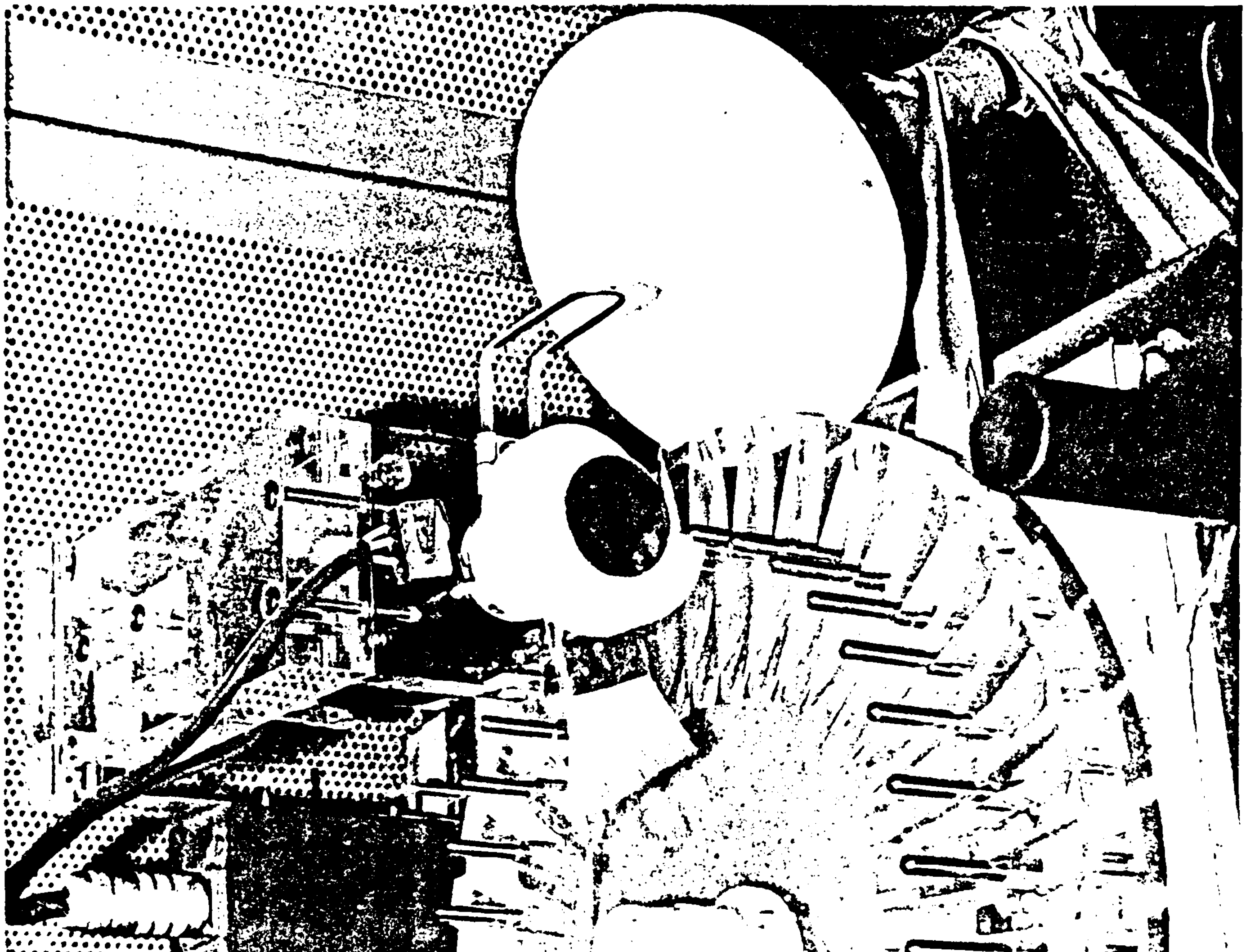


Figure 1-2. Food Distribution Apparatus.

3. To design and build a pig cart so that flat reflecting surfaces are minimized. Furthermore, the cart design should include considerations to reduce noise caused by the animal. For example, the cart should not squeak when the pig shifts its weight, and the floor of the cart should be padded to reduce noise caused by the animal's hoofs.

4. All pigs used in future studies should be examined for the presence of excessive ear wax and/or middle ear infections.

5. All pigs used in future studies should be young adults.

6. To identify and eliminate aberrant animals (due to illness or other factors) from further studies, once the normal hearing range for the minipig has been determined. Until the normal range of hearing for the minipig has been established, it is recommended that animals with a history of illness not be included in future studies.

7. The go-no-go procedure did not prove to be an effective testing method. It should be pointed out that an effective go-no-go procedure probably could be developed but would require additional experimentation. It is recommended, therefore, that the two-choice procedure be used in future studies since this procedure proved effective.

1.6 SUMMARY

The minipig would probably be a good animal for studying high-peak pressure impulse noise-induced hearing loss if:

1. The condition of the animal is good, i.e., no age or health related problems exist.

2. The test apparatus is modified.

3. The two-choice procedure is used.

SECTION 2

INTRODUCTION

2.1 OBJECTIVE

The primary goal of this work was the development of a rapid, reliable and valid psychophysical technique for the assessment of pure tone audiograms in the minipig.

2.2 BACKGROUND

Current animal models (chinchillas) can be used to investigate the effects of impulse noise which does not exceed 160 dB (re: .0002 dynes/cm^2), (Hamernik, Henderson, Crossley and Salvi, 1974; Henderson and Hamernik, 1975). However, beyond 160 dB the chinchilla's tympanic membrane perforates or ruptures (Eames, Hamernik, Henderson, and Feldman, 1975). It has been estimated that the threshold or tympanic membrane rupture in man is about 185 dB (von Gierke, 1966). Since the US Army's XM198 Howitzer and other weapon systems develop peak pressures in the 180 dB range, it was deemed necessary to develop a large animal model capable of withstanding these high-peak pressures.

2.3 ANIMAL SELECTION

The minipig was selected because of its size (90-150 lbs), suspected high threshold for tympanic rupture, suspected similarity of its hearing to man, ease of its care, and its reportedly high intelligence. Thus, the minipig might be an ideal large animal model for studying intense noise-induced hearing loss.

2.4 TECHNIQUES

A large number of psychopysical techniques have been developed over the years (for a review see Stebbins, 1970), all of which may provide similar audiograms. However, there is considerable variation between these techniques in the duration of training and testing necessary to obtain reliable audiograms. For

example, the "conditioned suppression" technique gives reliable results, but requires a protracted period of training in order to establish a high and steady response baseline (Smith, 1970). Furthermore, relatively few test trials can be obtained in a single session (Heffner R., Heffner H., and Masterton, 1971). Thus, this technique requires several months to establish a reliable audiogram. Other methods, such as the two-choice and go-no-go techniques, have yielded reliable and valid results with less training and testing over a wide range of species (Burdick and Miller, 1973, 1975; Francis, 1975, Herman and Arbeit, 1973; Mohl, 1968; Terhune and Ronald, 1972; Heffner, personal communication). Our approach, therefore, focused on these two techniques.

SECTION 3

METHOD

3.1 APPARATUS

The intelligence panel consisted of a plywood board on which two plexiglass "keys" (6" x 6") were placed on each side of a hole (6" x 6"), (see Figure 1-1). A photo cell and a light were attached so that the photo cell could detect the presence of the pig's nose in the hole. A small light was positioned 3 inches above the center hole. The "keys" to the left and right of the center hole were hinge-mounted and actuated a micro switch when depressed. A small light was mounted on the back of each "key". The intelligence panel was mounted by means of pipe and wood screws to a plywood ramp. The plywood ramp contained slots which held the pig cart in place (see Figure 3-1). The pig cart was modified so that the pigs could obtain access to the intelligence panel and the food trough (see Figures 3-2, 3-3).

A D.S.I. Feeder (Model 310) was used to deliver a good reward by dumping food into a funnel-tube. The tube emptied into a wood trough mounted on the front of the intelligence panel just below the center hole. All switches, lights and the feeder were connected to an interface panel (custom-made). Programming and control functions were accomplished with Coulbourn logic modules (see Appendix A). The output from and input to the modules was via the interface panel (see Figure 3-4).

The sound system consisted of an oscillator (Kroh-Hite, Model 4100R) which was connected to a signal gate (Coulbourn, Model S84-04) and a frequency counter (Autometronic, Model 5500B). The signal gate was attached to a Hewlett-Packard Attenuator (Model 437A). The attenuator was then connected to an amplifier (Altec, 1594B), the output of which led to a speaker (Atec, Model 612C) and a RMS voltmeter (Fluke, 8920A). The intelligence panel, pig cart, feeder and speaker were housed in an IAC sound-treated chamber. The animal behavior could be monitored via a video camera (Sony, AVC 1400) mounted inside the IAC chamber.

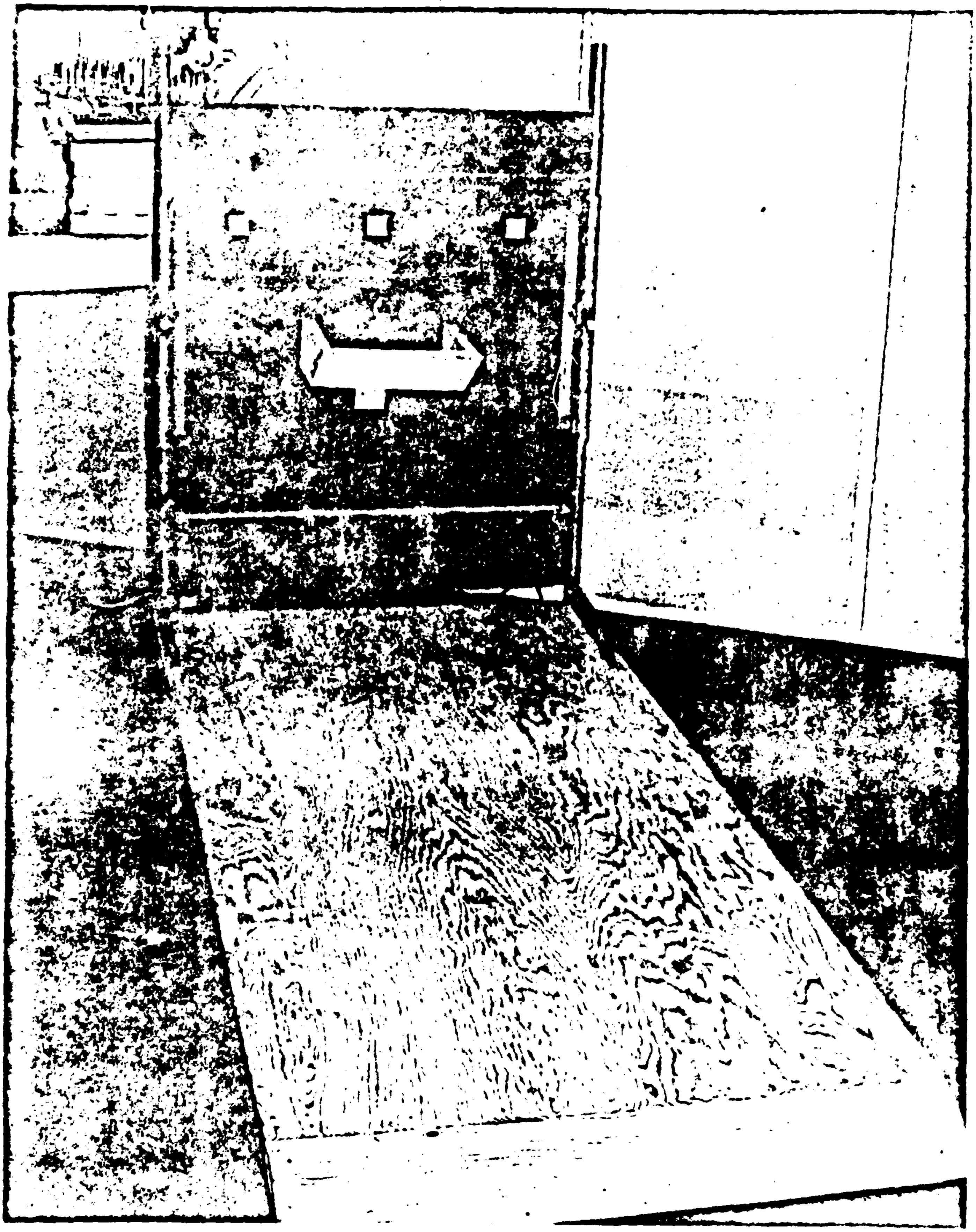


Figure 3-1. Intelligence Panel.

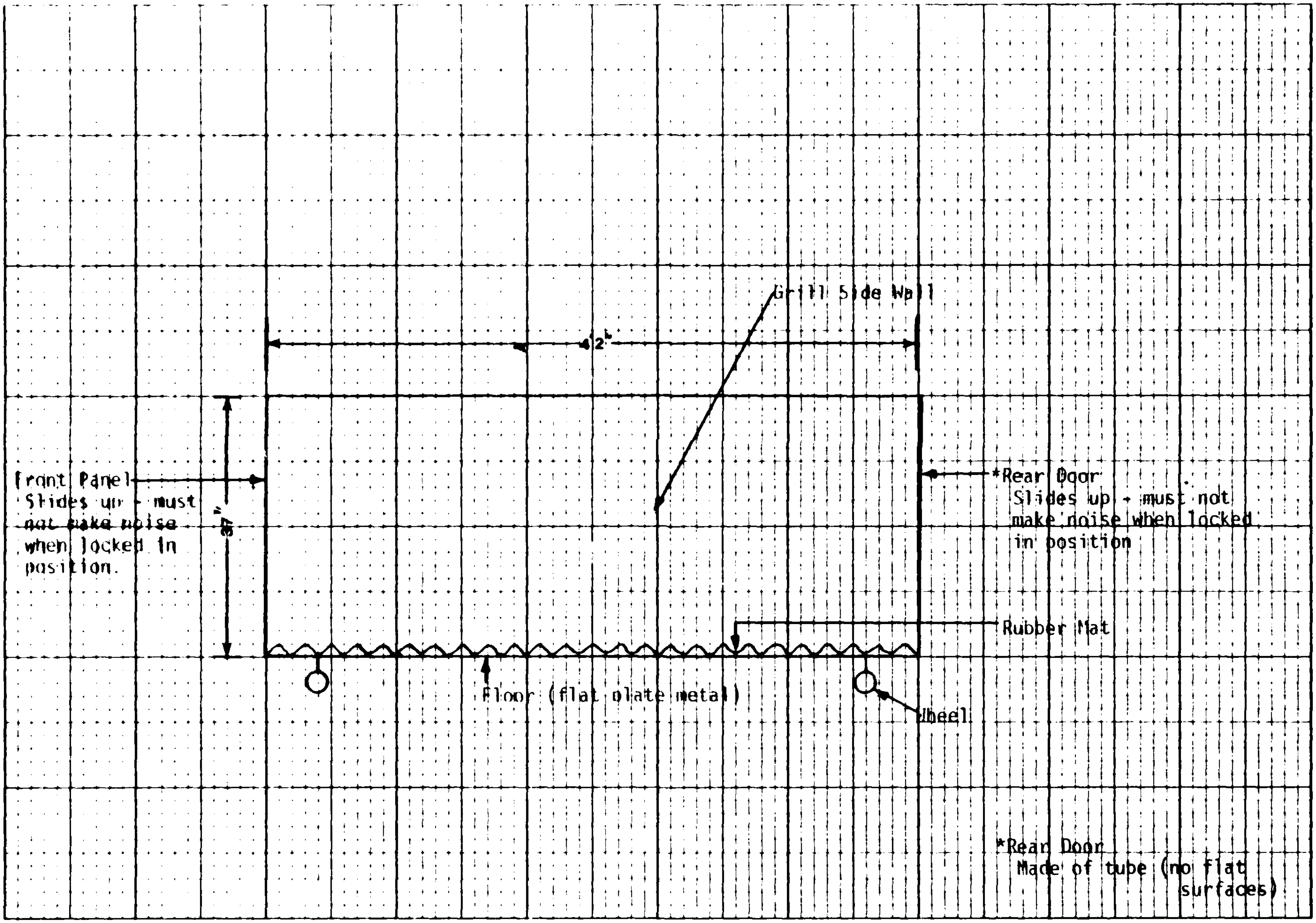


Figure 3-2. Pig Cart, Side View.

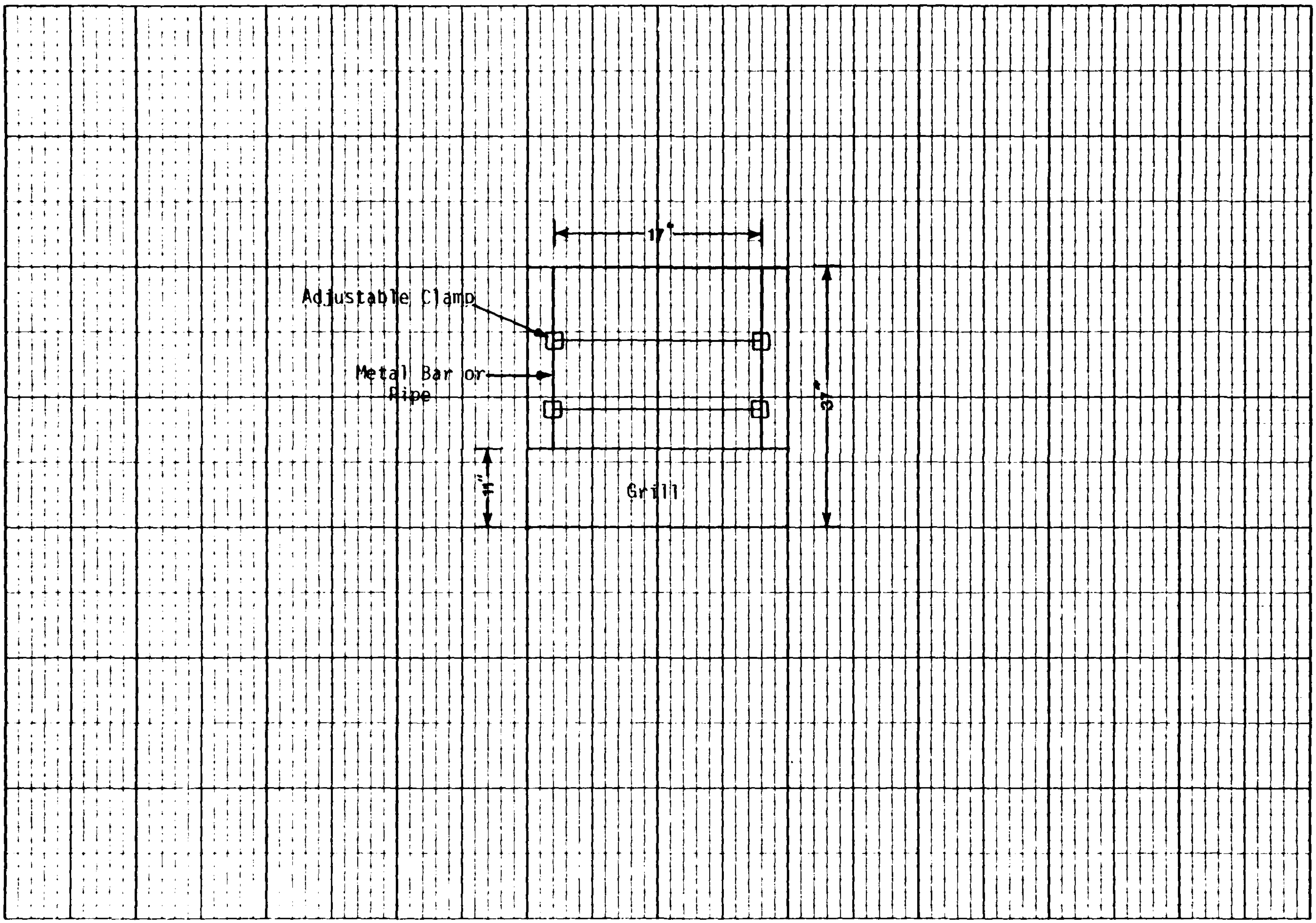


Figure 3-3. Pig Cart, Front View of Front Panel.

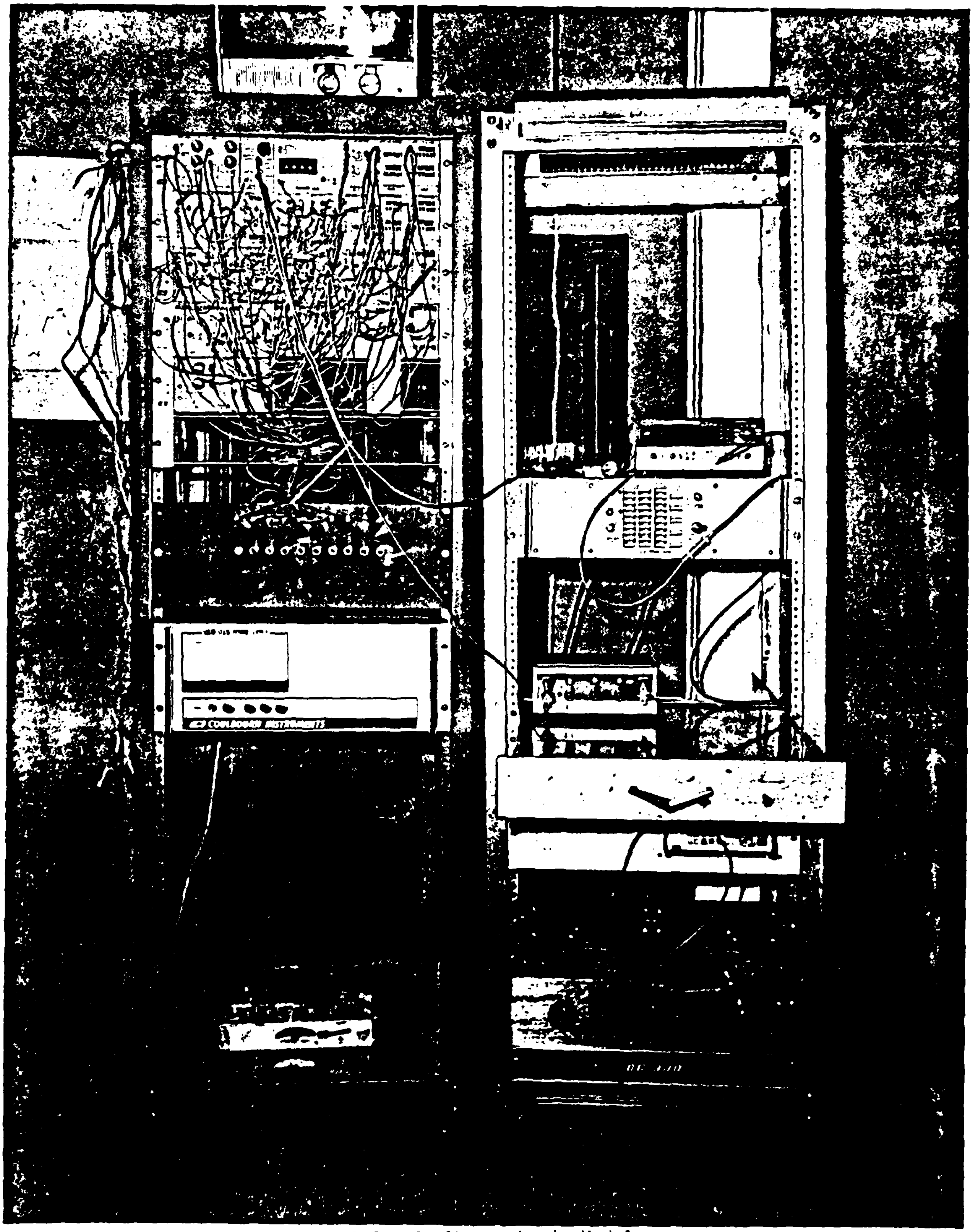


Figure 3-4. Coulbourn Logic Modules.

3.2 TWO-CHOICE

Training Procedure

The pigs are trained first to make the observing response, then to make a left-right discrimination using the lights mounted on the keys as cues. Finally, the pigs respond to the left in the presence of a tone and to the right in the absence of a tone (see Figure 3-5).

Observing Response

During the first session, a pig deprived of food for 24 hours is trained to place its nose in the hole, thus deactivating the photocell, in order to obtain a small amount of food (10 gms/reward, "Hog Grower" FRM). Once the animal makes the observing response, the observing response light mounted just above the hole is turned off. After a short time (25 seconds), the observing response light is turned on again to indicate that another trial can be initiated.

Side Response

During the following session, an observing response turns on one of the key lights, and the pig is then required to depress that key in order to obtain a reward. Initially, responses to the incorrect key are not counted and do not terminate the trial. After 30-50 trials, this procedure is repeated with the other key. Once the pig has learned this sequence (in 60-100 trials), the determination of the correct side is then randomized by a quasi-random schedule (Gellerman sequence) so that each side is correct half of the time. If the pig makes an error (depresses the unlit key), the trial is terminated, the light on the correct side is turned off, and a time-out of 15-20 seconds is initiated. Following the time-out, the observing light is turned on, and the animal is permitted to initiate a new trial. To reduce the possibility of a side preference, a correction procedure is used in which the correct side does not change following an error. As a result of this procedure, responses to trials following an error are not included in calculating the animal's performance.

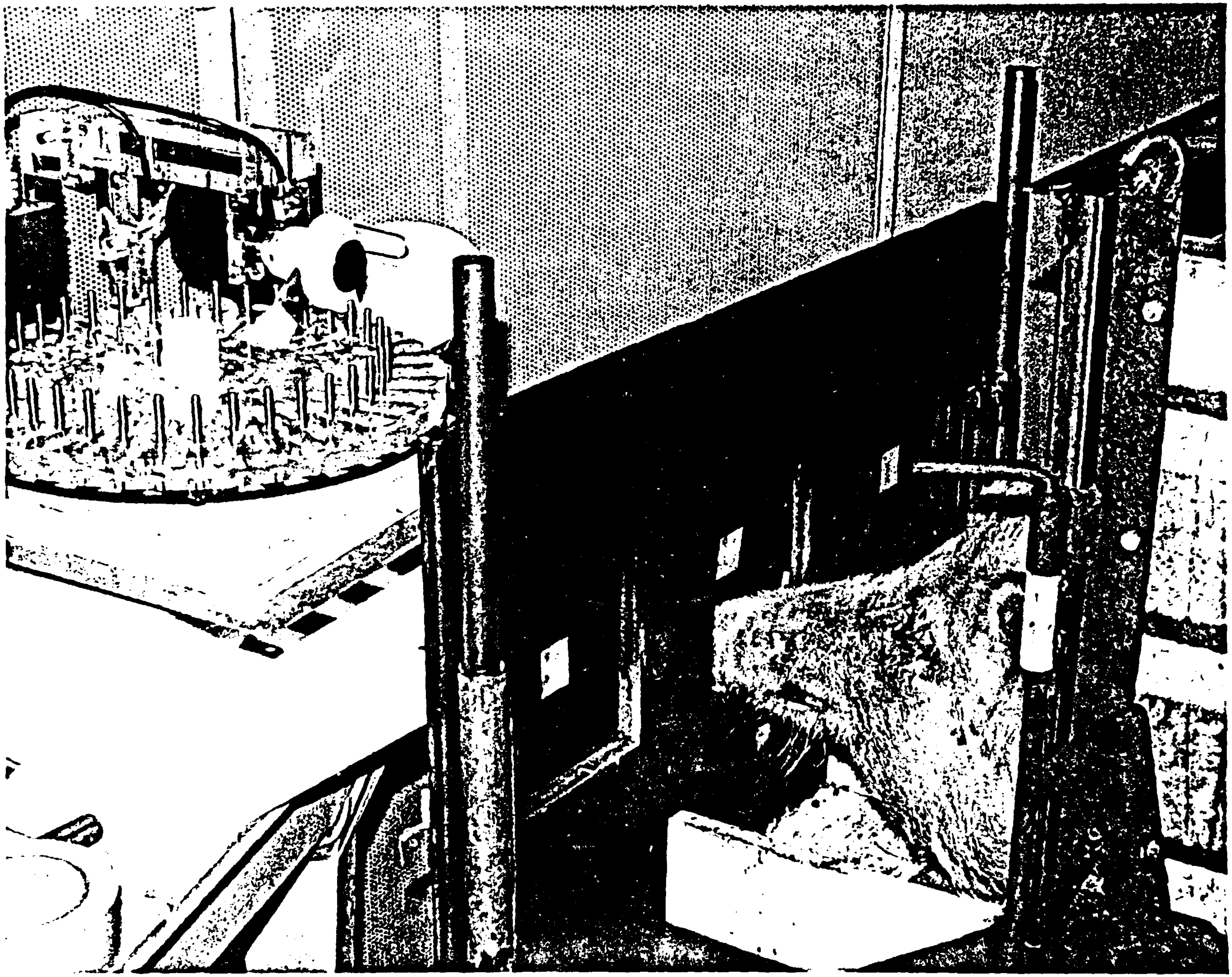


Figure 3-5. Pig Initiating Trial Sequence.

Visual Discrimination

The purpose of the visual discrimination task is to accustom the animals to performing 150-200 trials per hour at an accuracy level of at least 95%. This task is ideally suited for this purpose because the animals are usually able to learn the discrimination in 10 to 20 trials. Thus, it is possible to train them to respond quickly and efficiently without confusion of a more difficult discrimination.

3.3 AUDITORY TRAINING

Once the pigs have learned the visual discrimination, three changes are introduced to prepare the animals for auditory testing. First, an obviously supra-threshold tone is presented during trials in which the left side key is correct. The tone comes on when the animal makes an observing response and goes off after a side response has been made. Secondly, the animal is gradually required to maintain the observing response for longer periods of time (up to three seconds) before a side response can be made. Following successful introduction of the above changes, the visual cue is gradually eliminated and the animal is required to rely upon the presence or absence of the tone to indicate the correct side. This final change is accomplished by turning on both side lights at the end of the observing period so that the lights continue to indicate when a side response can be made even though they no longer indicate the correct side.

Additional Training

Once the pig has learned to perform the auditory discrimination at high performance levels, additional training is given to enable the animal to become a reliable and experienced observer. This training consists of presenting tones of different frequencies and intensities. It is particularly important that the pig be trained to respond to low-intensity tones before threshold testing is begun. One to two weeks of such training is usually necessary. From start to finish, the entire training period takes approximately 20 to 30 daily sessions.

Threshold Determination

Threshold determination is conducted in two ways. First, the threshold for a particular frequency is estimated by reducing the intensity of the tone in steps of 10 dB, with blocks of 20 trials given at each intensity. Once an estimation of threshold has been obtained, a second threshold determination is conducted by presenting tones with intensity levels in 5 dB increments extending from 10 dB below to 10 dB above the estimated threshold. At least 50 trials are given at intensities just above and below threshold with threshold defined in terms of the 0.01 one-trial level of significance (binomial distribution). The two-choice procedure is identical to the one developed by Henry Heffner (unpublished manuscript).

3.4 GO-NO-GO PROCEDURE

The go-no-go procedure was tested as an alternate method, but proved to be ineffective. This procedure differed from the two-choice procedure in two ways. First, after making the observing response, the animal had three seconds once a tone was presented in which to correctly indicate its presence by depressing the left key and receiving a reward. Secondly, after making the observing response and receiving no tone at all, the animal had to refrain from depressing the left key for three seconds in order to obtain a reward. The specific problems encountered with this procedure will be discussed in greater detail in Section 5 of this report.

3.5 SUBJECTS

Three minipigs, approximately 4.5 years of age were used as subjects. All three had a history of illness with associated fever and drug treatment. No known ototoxic drugs were administered to these animals. Several months prior to training, pig 174 had ingested a large quantity of heart worm medicine and almost died. Later, both pigs 174 and 184 became ill during testing. Testing was halted temporarily to allow the animals to recover.

3.6 SOUND FIELD MEASUREMENT

Sound field measurements were made in the area occupied by the pig's head during an observing response. Twenty-four locations were selected. Throughout these measurements, a constant voltage for a given frequency was maintained at the speaker input. Measurements were made using a Brüel and Kjaer measuring amplifier (type 2606) and a Brüel and Kjaer 1/4 inch condenser microphone (type 4136). The mean of the twenty-four intensity readings for a given frequency was used as the reference point for calculating thresholds. A table containing the twenty-four intensity readings for each frequency, along with the mean intensity for each frequency, is shown in Table 3-1.

TABLE 3-1. VARIATION IN INTENSITY OF
PURE TONES IN THE SOUND FIELD

Microphone Position	.063	.125	.250	.500	1	2	4	8	16
					Frequency in KHz				
1	85	86	86	88	81	87	94	86	81
2	83	84	84	80	85	92	80	86	79
3	82	84	88	85	82	85	86	86	80
4	83	82	86	81	86	84	87	81	82
5	83	81	82	83	87	82	87	84	81
6	83	83	81	90	87	89	88	91	85
7	84	90	77	90	88	82	87	77	71
8	84	78	79	83	84	89	89	86	82
9	85	80	82	81	88	83	87	72	79
10	84	84	85	89	76	89	88	88	86
11	83	83	85	79	90	89	85	91	76
12	82	82	87	86	80	91	85	88	70
13	83	81	85	82	87	88	83	83	82
14	83	81	81	83	91	86	76	86	82
15	84	83	81	91	88	88	84	83	78
16	85	78	77	88	88	83	83	77	72
17	85	77	79	82	86	82	86	72	78
18	85	79	82	82	85	75	89	84	79
19	82	83	87	84	85	82	83	74	81
20	83	83	84	78	87	84	92	88	83
21	85	79	80	80	87	79	87	84	72
22	82	84	86	82	85	84	76	92	86
23	83	82	83	79	89	89	73	90	84
24	86	79	79	81	87	82	86	74	74
db Variation	4	13	11	13	15	17	21	20	16
Mean Intensity dB	83.63	81.92	82.75	83.63	85.79	85.17	85.04	83.46	79.29

*NOTE: Readings for microphone positions for the designated frequency are given in sound intensity (dB) (Re: .002 dynes/Cm^2)

SECTION 4

RESULTS

4.1 PSYCHOPHYSICAL FUNCTIONS

The minipigs learned the two-choice procedure rapidly (20-25 sessions). An example of a typical psychophysical function is shown in Figure 4-1 for 63 Hz. The threshold for 63 Hz for pig 184 was 39 dB, which is close to that of both the chinchilla and man (see Figure 4-2). Additional psychophysical functions for both pigs at all frequencies tested can be found in Appendix B. A complete audiogram is shown in Figure 4-3. It is evident that the minipigs tested exhibit relatively high thresholds (as compared to chinchilla and man) for frequencies between 500 Hz and 4 KHz. The audiogram shown in Figure 4-3 should not be considered as representative of minipig hearing, however, since several mitigating factors may have contributed to these high thresholds. These factors will be pointed out in Section 5 - DISCUSSION.

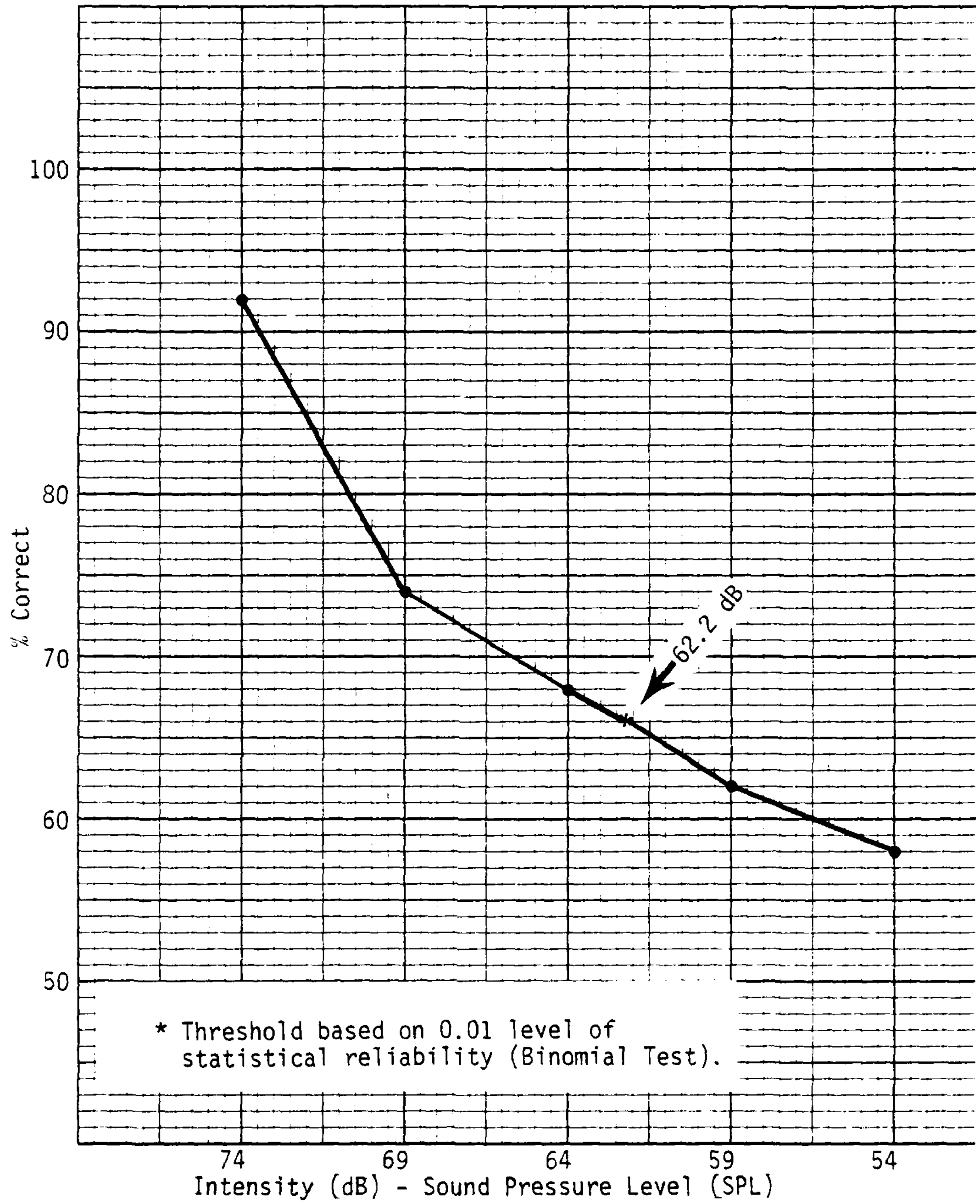


Figure 4-1. Audiogram, 63 Hz: Pig 174.

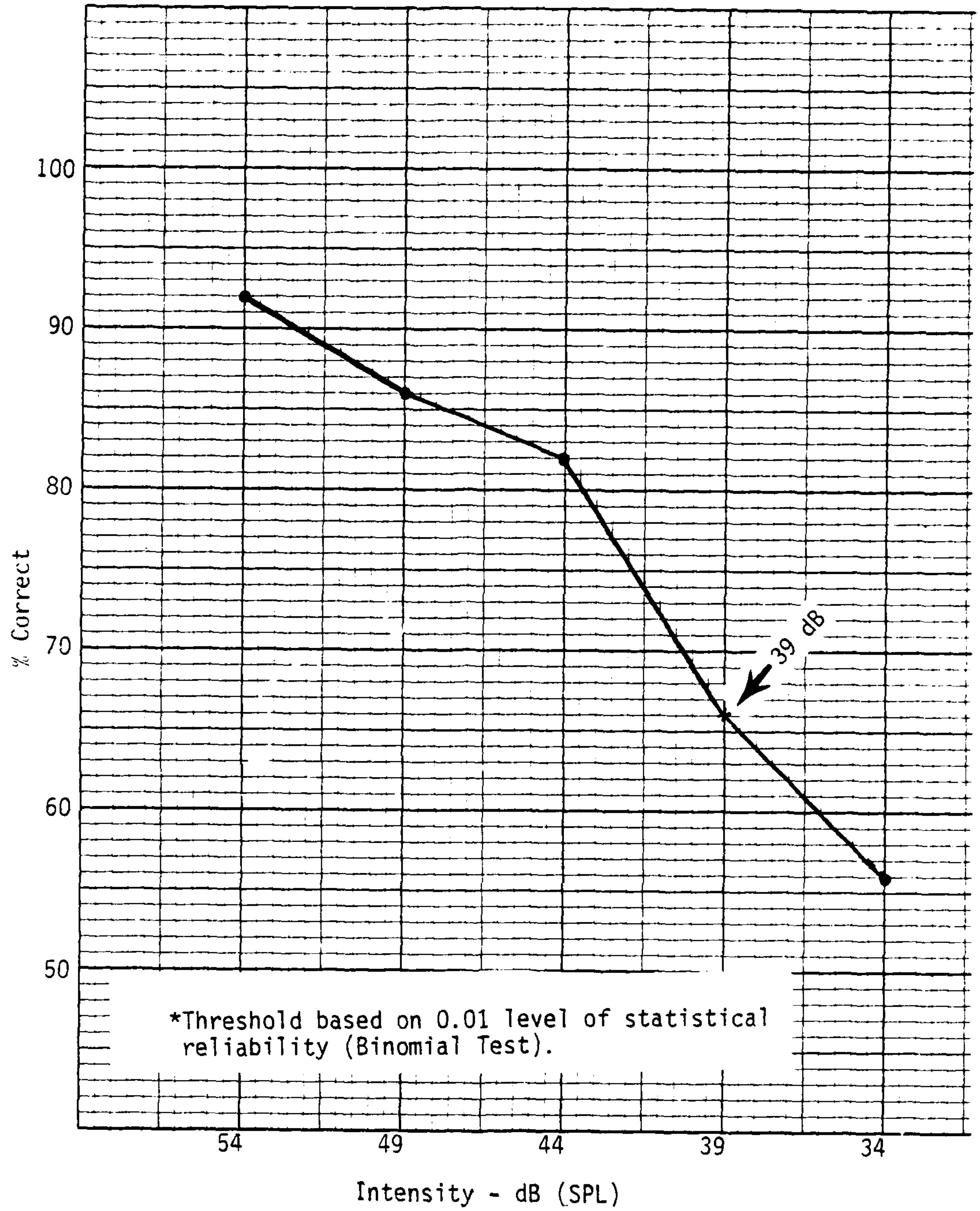
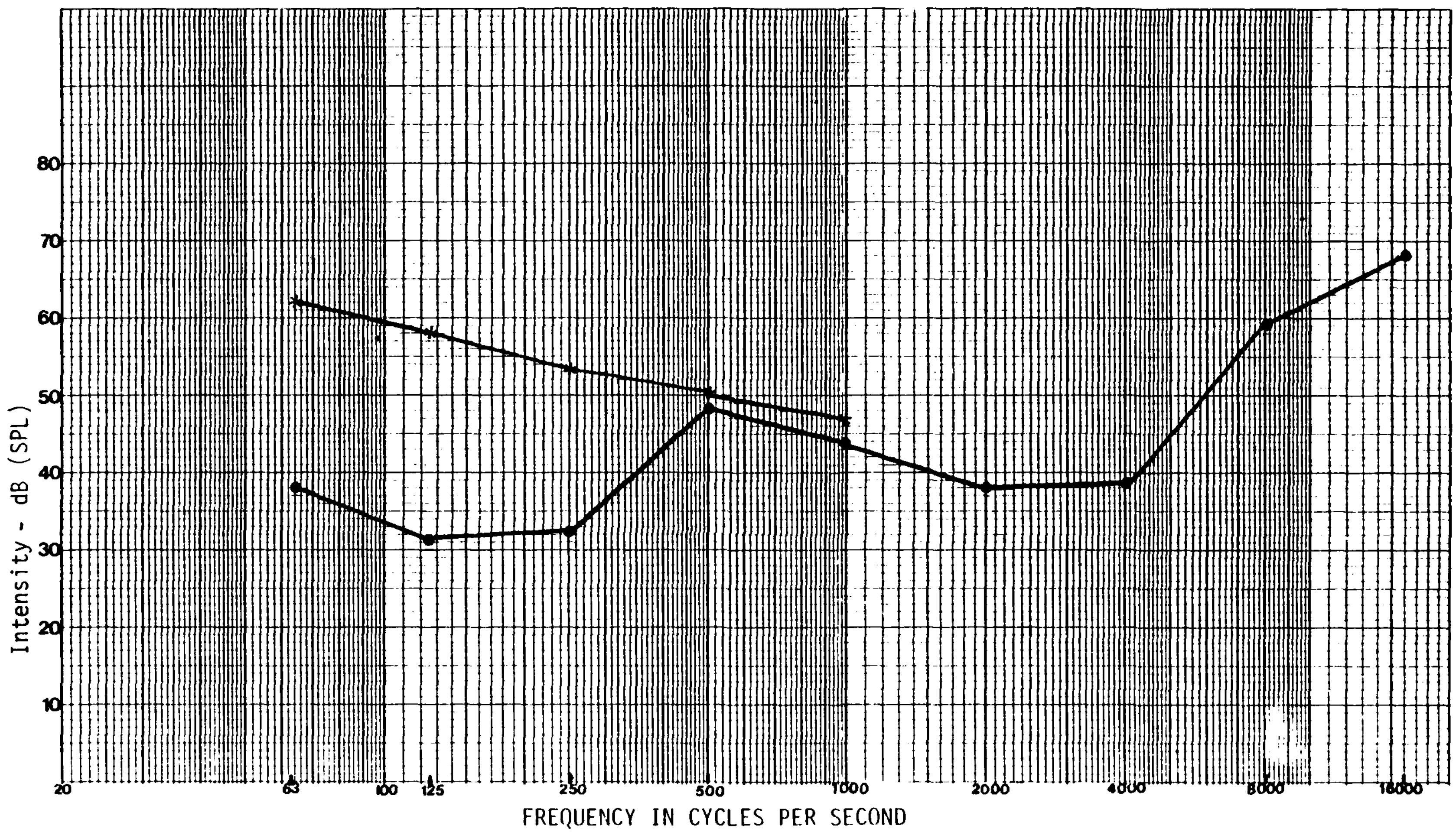


Figure 4-2. Audiogram, 63 Hz: Pig 184.



Remarks:

*For Pig 174

●For Pig 184

For frequencies above 1000 Hz, data for Pig 174 was not reliable.

Figure 4-3. Pig Audiogram.

SECTION 5

DISCUSSION

5.1 HIGH THRESHOLDS

It was pointed out previously that the minipigs tested exhibited high thresholds for tones between 500 Hz and 4 KHz. Several possible factors, which can be divided into two major categories, may have contributed to these high thresholds.

Physical Condition

First, the condition of the animals themselves is suspect. Each of the animals had a history of illness with associated fever, and it is possible that the pigs suffered some hearing loss as a result. In addition, when the pigs' ears were examined on two occasions, large amounts of earwax had to be removed from the ear canals. This wax had essentially formed a plug which would have markedly attenuated sounds. Although treatment with Debrox (International Pharmaceutical Corp) was initiated, earwax buildup was a constant problem. Furthermore, the pigs were more than four years of age. Since arriving at USAARL, they had been housed in open air cages adjacent to a large vibration table. When the vibration table was in operation it was possible to feel the vibrations via the feet and legs by merely standing on the concrete in the animal housing area. It is conceivable that the age of the minipigs and/or the exposure to vibration may have contributed to a hearing loss.

Sound Field

Secondly, the sound field measurements made in the area around the observing response indicated that there were large variations in intensity. These variations were small for frequencies below 500 Hz, but increased markedly for higher frequency tones (as much as 21 dB). (See Table 3-1 for table of sound field measurements.) The large variations in the sound field may have contributed to the high thresholds. For example, if an animal's head was in a position in the

field where the sound was not very intense an apparently high threshold would result. This would occur because the average of all sound field measurements was used as the basis for a particular voltage input to the speaker.

5.2 GO-NO-GO PROCEDURE

The one pig (176) which was specifically identified to be trained on the go-no-go method never learned the test procedure. Two ambiguities in this procedure are thought to be the cause for its inability to learn the go-no-go task.

First, during no-go trials the animal would often refrain from making a response for three seconds (the correct behavior). However, as the food was coming down the tube, the animal would depress the go-key. Thus, even though the animal initially made a correct response, the close temporal relationship of the reward with the key-pressing response of the pig, may have surreptitiously reinforced the incorrect response. Typically, after one of these trials, the pig would then press the go-key for several no-go trials (an error).

Secondly, during the go trials the pig would often press the go-key only fractions of a second after the three-second time limit had expired (an error). However, from the point of view of the pig, the tone may still have appeared to be audible. In other words, the pig was not rewarded for an apparently correct behavior.

In order for the go-no-go procedure to be effective, modifications in the procedure would have to be made so that the possibility of an ambiguous situation is eliminated.

SECTION 6

RECOMMENDATIONS

6.1 DETAILED RECOMMENDATIONS

Based on the conclusions and results of this research project, it seems appropriate that the following recommendations be made:

1. Redesign the intelligence panel so that flat reflective surfaces are minimized. (Note: Design included in Figure 1-1.)

2. Switch to a liquid reward system which uses a solenoid valve. This would eliminate most, if not all, of the mastication noise and would allow the inter-trial interval to be reduced. Thus, a greater number of test trials could be obtained in less time.

3. Design and build a pig cart so that flat reflecting surfaces are minimized. Furthermore, the cart design should include modifications to reduce noise caused by the animal. For example, the cart should not squeak when the pig shifts its weight and the floor of the cart should be padded to reduce noise caused by the animal's hoofs.

4. All pigs used in future studies should be examined for the presence of excessive ear wax and/or middle ear infections.

5. All pigs used in future studies should be young adults.

6. After having established the normal hearing range for the minipig, animals which are aberrant (due to illness or other factors) can be identified and eliminated from future studies. Until the normal range of hearing for the minipig is established, it is recommended that animals with a history of illness not be included in future studies.

7. The go-no-go procedure did not prove to be an effective testing procedure. It should be pointed out that an effective go-no-go procedure probably could be developed but would require additional experimentation. It is recommended, therefore, that the two-choice procedure be used in future studies since this procedure proved to be effective.

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APPENDIX A
EQUIPMENT LIST

APPENDIX A

EQUIPMENT LIST

Coulbourn Equipment

Number	Description	Model Number
4	One Shot Timer	S52-53
2	Interval Timer	S53-10
1	Universal Timer	S53-21
3	Retriggerable One Stop	S52-12
1	Selectable Envelope	S84-04
1	Predetermining Counter	S43-30
4	Counter	R11-02
3	RS/T Flip Flop	S41-12
3	Or Gate	S31-12
10	And Gate	S31-12
2	Power Driver	S61-05
2	Switch Input	S22-02
3	Module Frame	S12-02
1	Solid State Power Supply	

Additional Equipment

Number	Description	Model Number
1	Altec Amplifier	1594B
1	Fluke RMS Voltmeter	8920A
1	Krohn-Hite Oscillator	4100R
1	Autometronic Counter	5500R
1	Hewlett-Packard Attenuator	4437A
1	Davis Scientific Instruments Universal Feeder	310
1	Sony Video Camera	AVC 1400
1	Video Power Unit	AVC 1400
1	Altec Speaker	612C
1	Sony TV Monitor	CVM 131
1	I.A.C. Sound Treated Chamber	107591

Custom-Built Equipment (JAYCOR)

Number	Description	Model Number
1	Interface	N/A
1	Intelligence Panel	N/A
1	Modified Pig Transport Cart	N/A
1	Ramp	N/A

Sound Measurement

Number	Description	Model Number
1	Measuring Amplifier, Brüel and Kjaer	2602
1	1/4" Condenser Microphone, Brüel and Kjaer	4136

APPENDIX B

AUDIOGRAMS, PIGS 174 AND 184

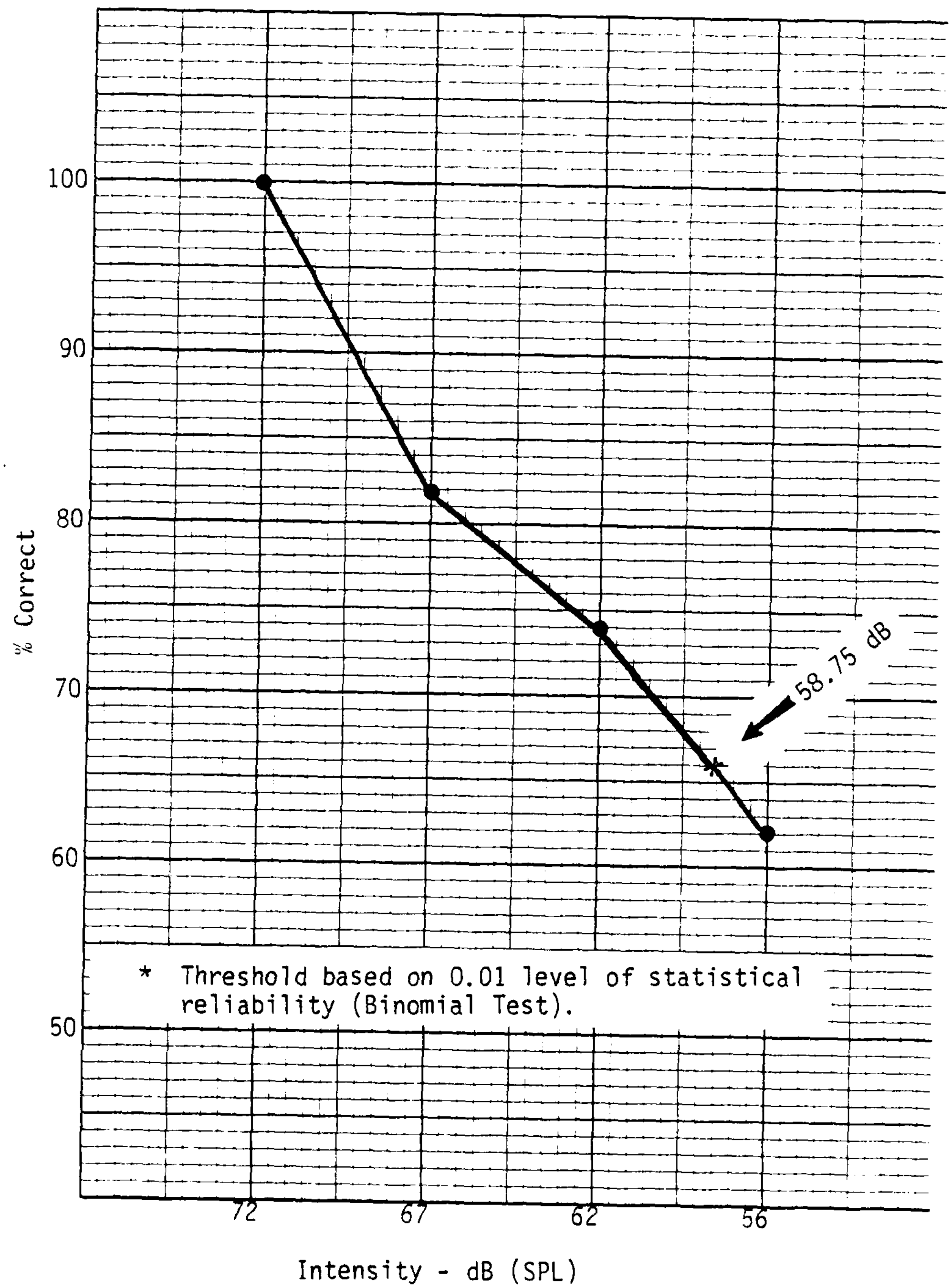


Figure B-1. Audiogram, 125 Hz: Pig 174.

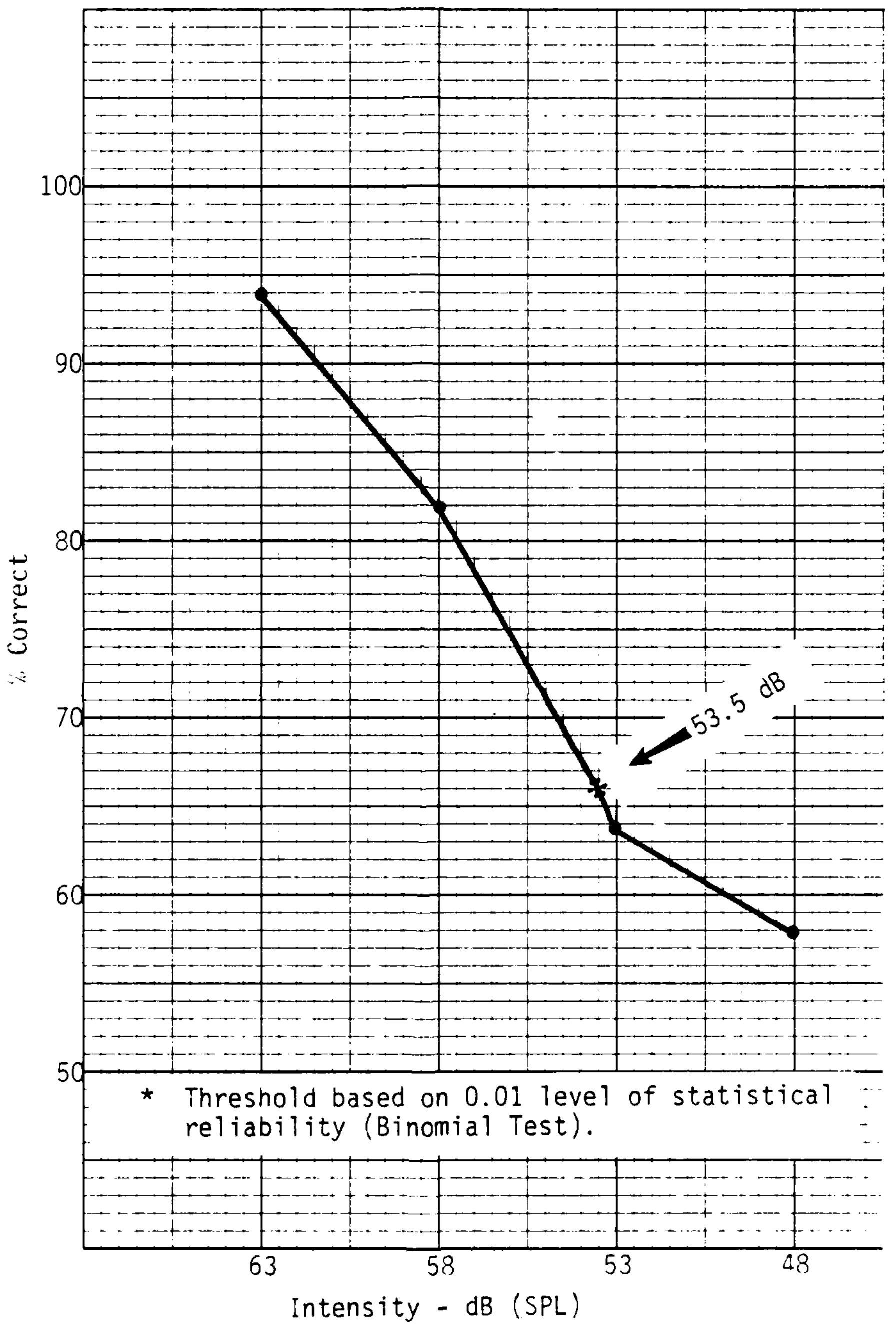


Figure B-2. Audiogram, 250 Hz: Pig 174.

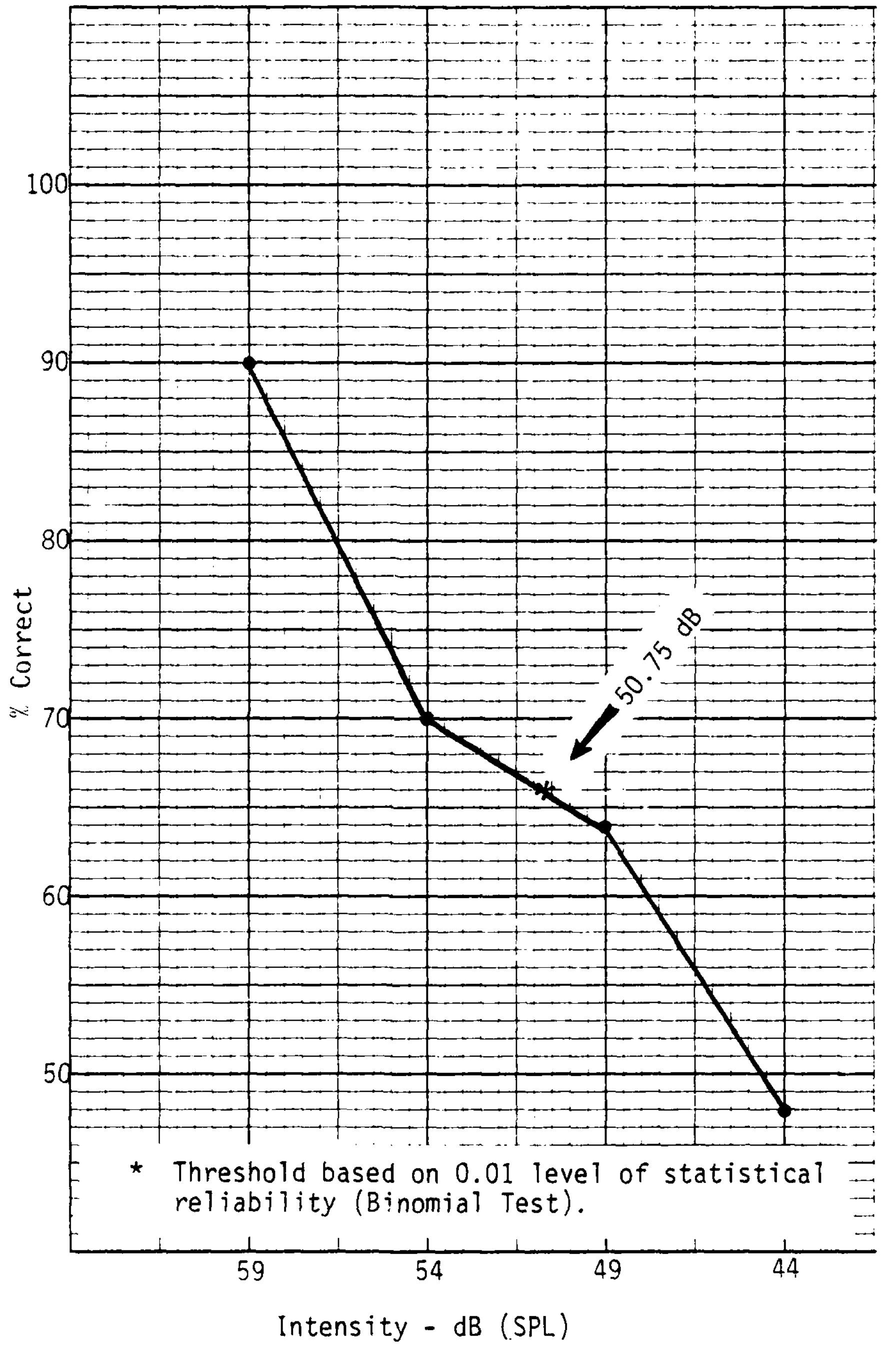


Figure B-3. Audiogram, 500 Hz: Pig 174.

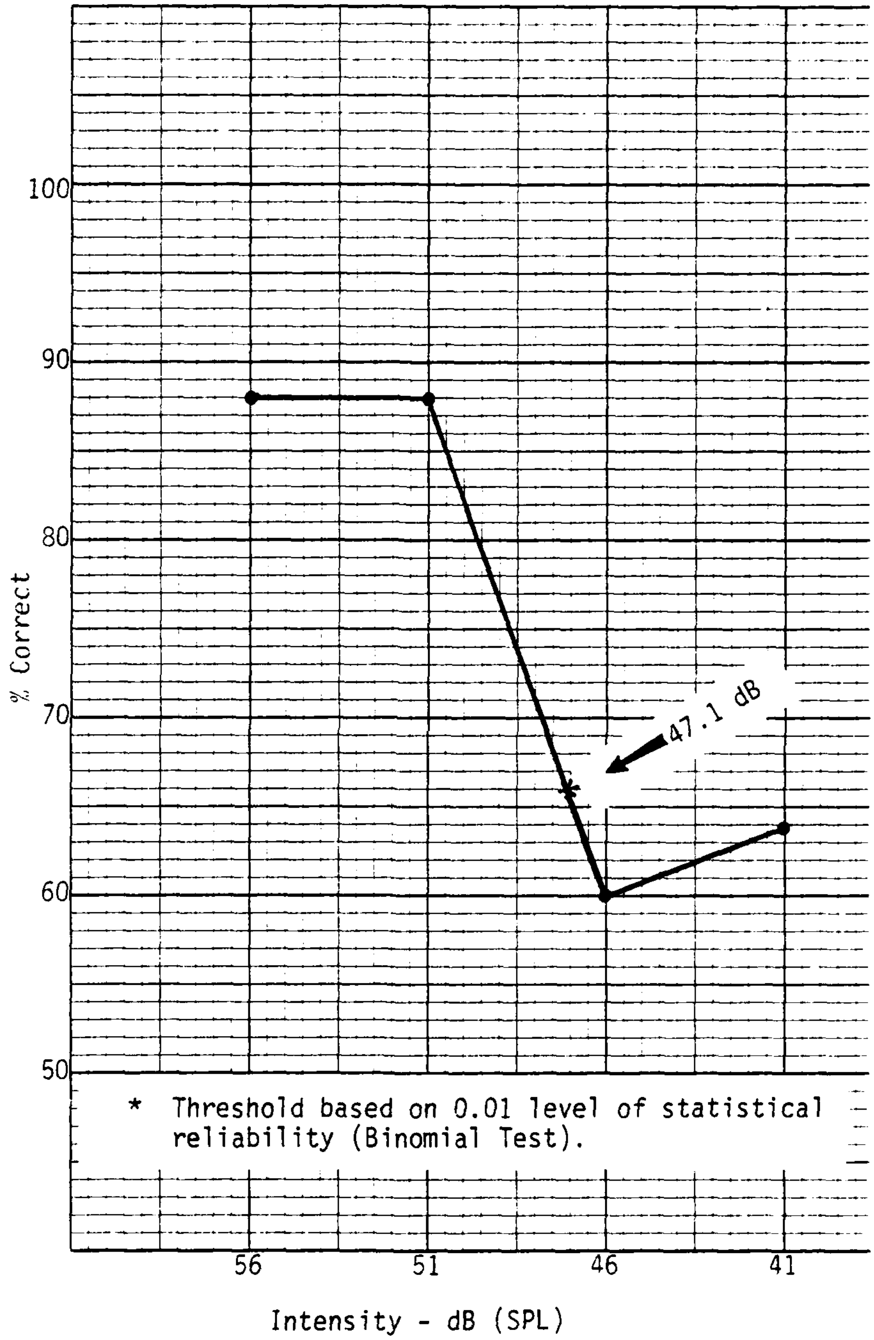


Figure B-4. Audiogram, 1 KHz: Pig 174.

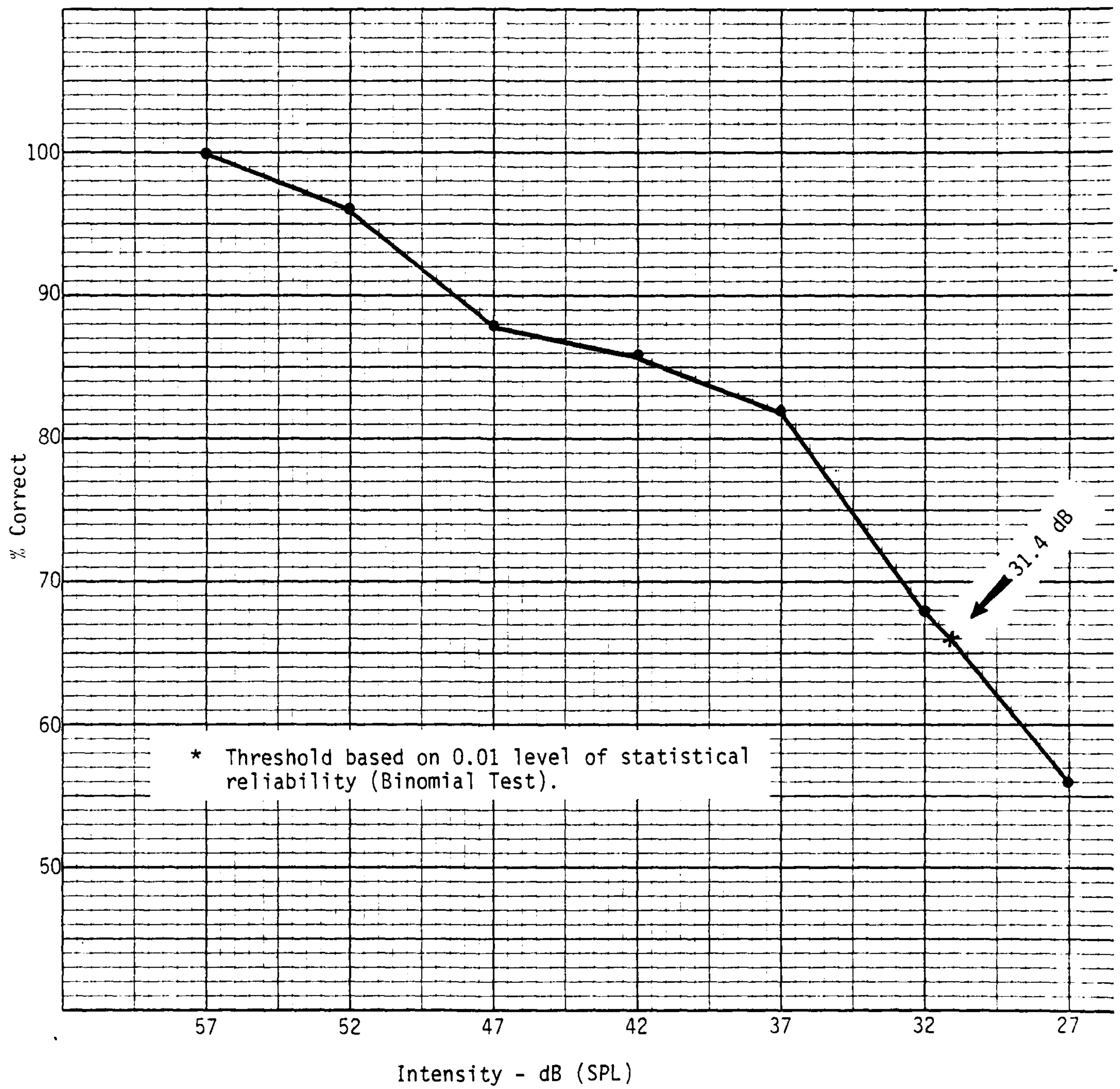


Figure B-5. Audiogram, 125 Hz: Pig 184.

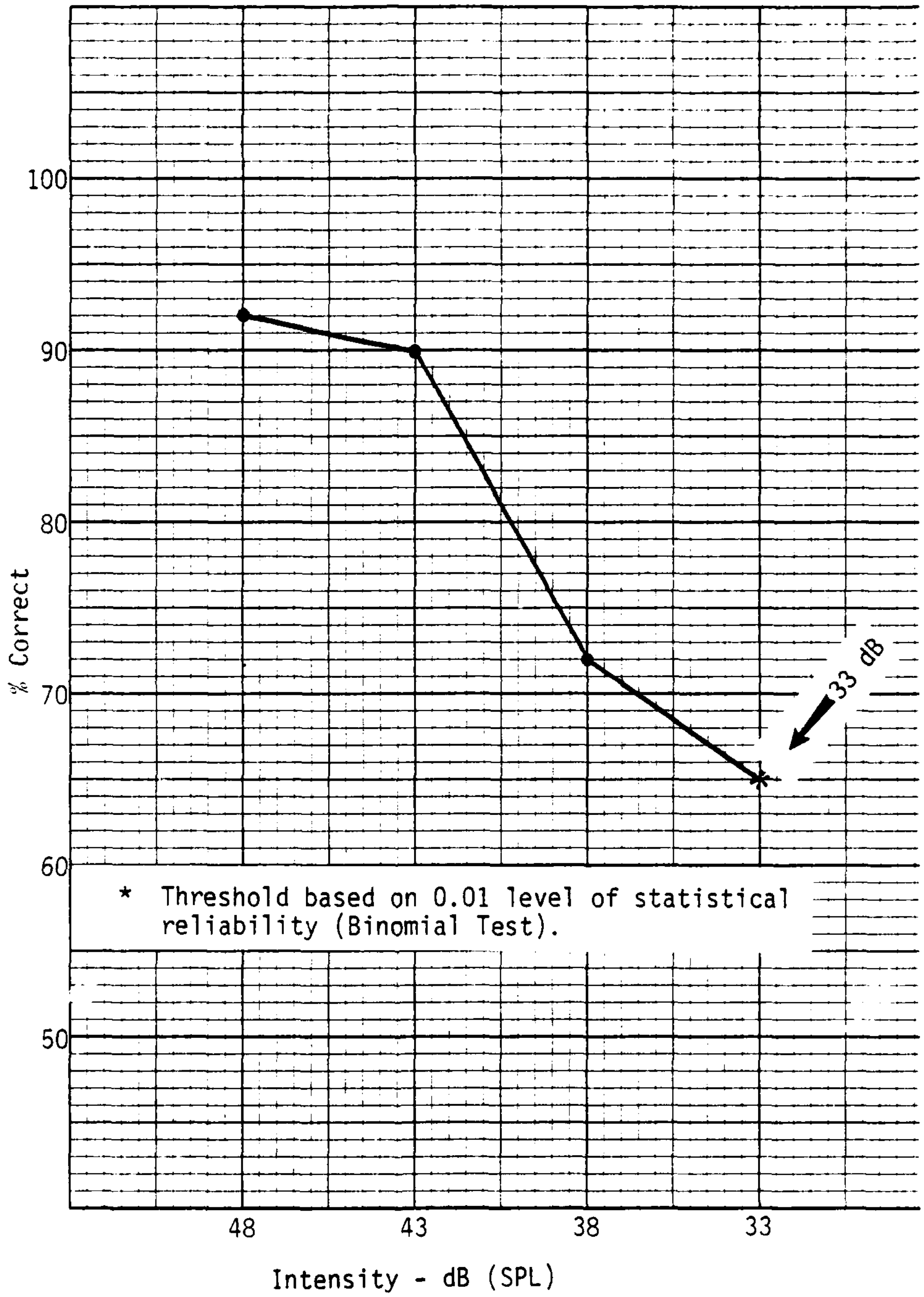


Figure B-6. Audiogram, 250 Hz: Pig 184.

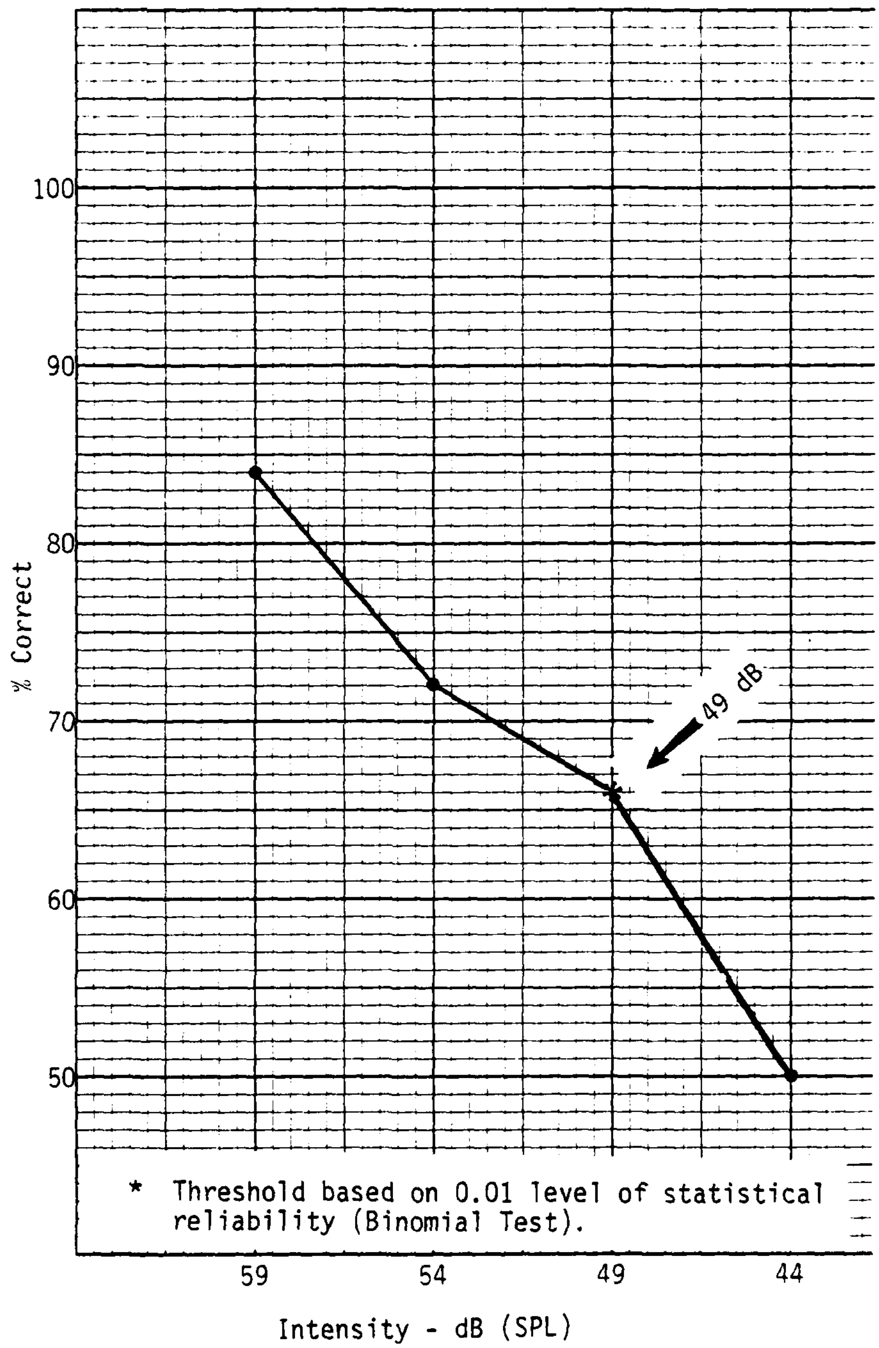


Figure B-7. Audiogram, 500 Hz: Pig 184.

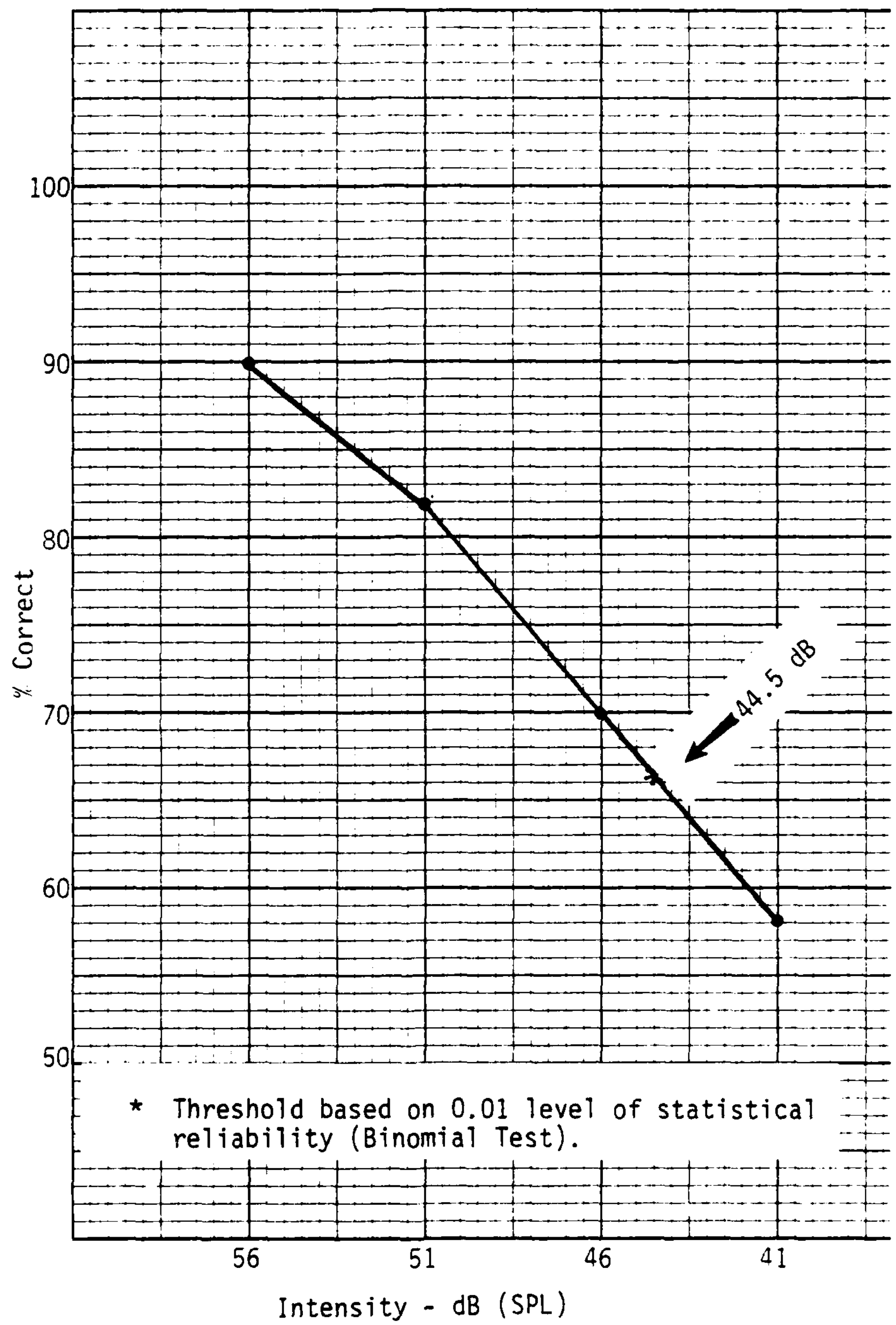
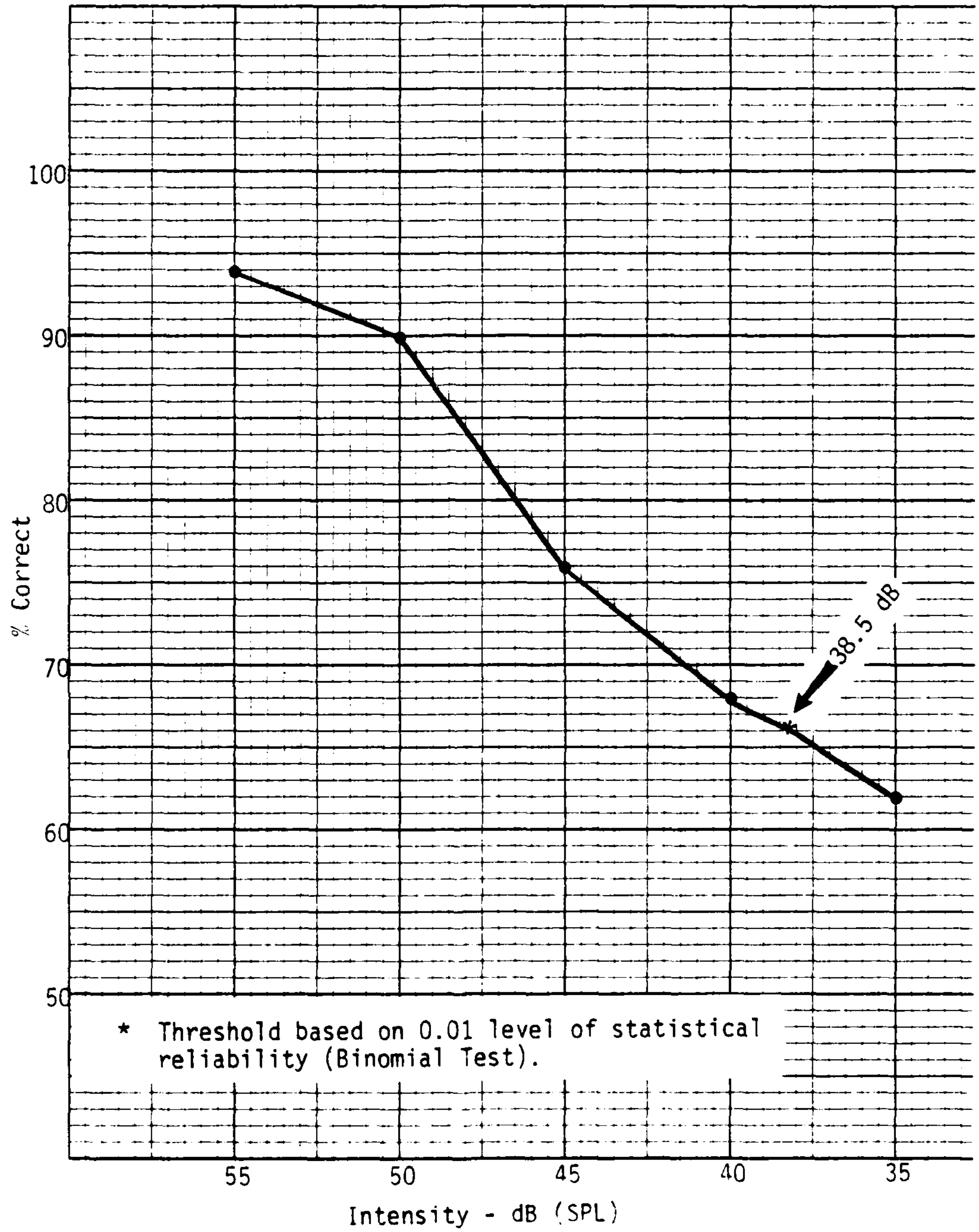


Figure B-8. Audiogram, 1 KHz: Pig 184.



Fiaure B-9. Audiograr, 2 KHz: Pig 184.

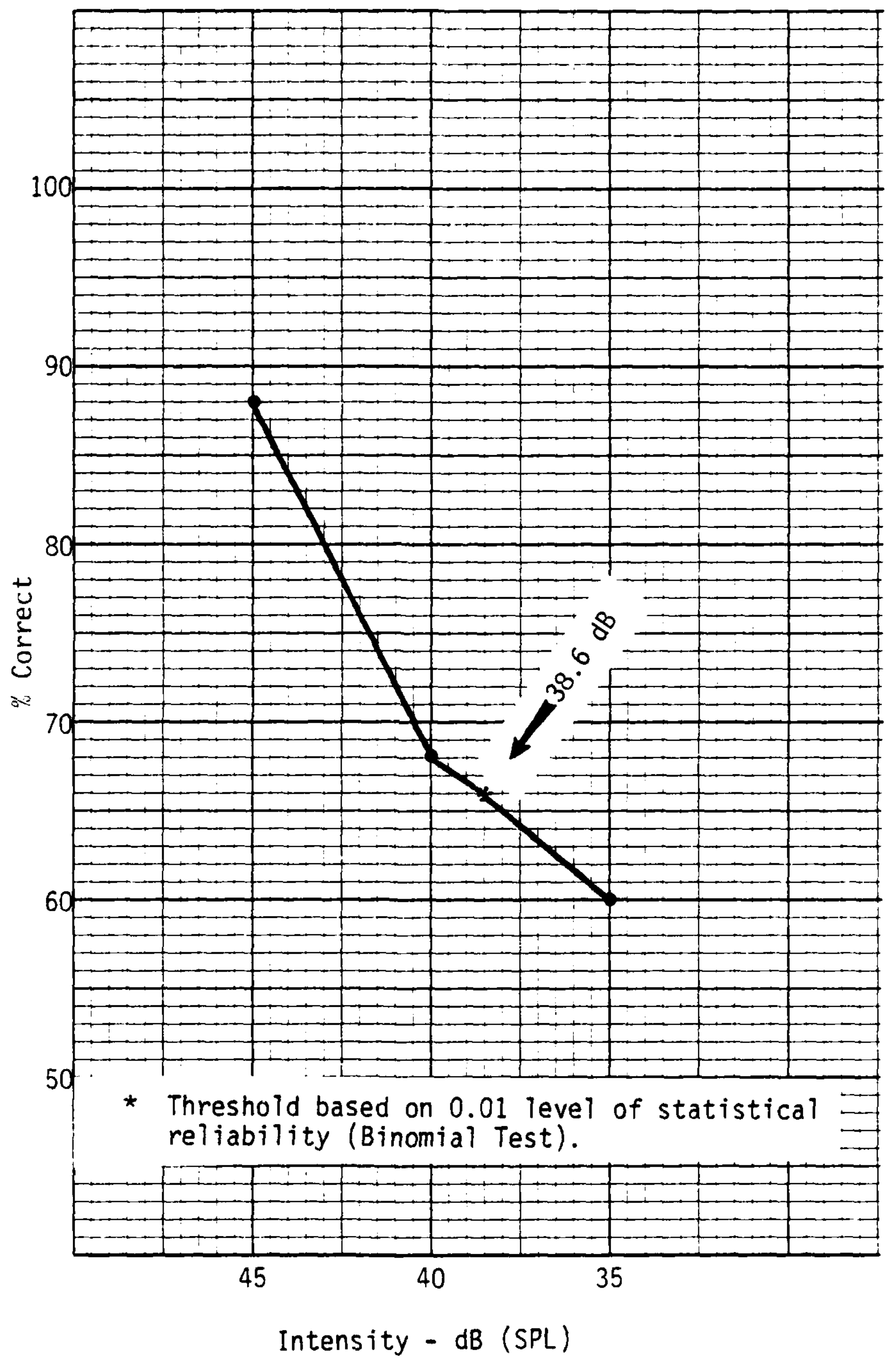


Figure B-10. Audiogram, 4 KHz: Pig 184.

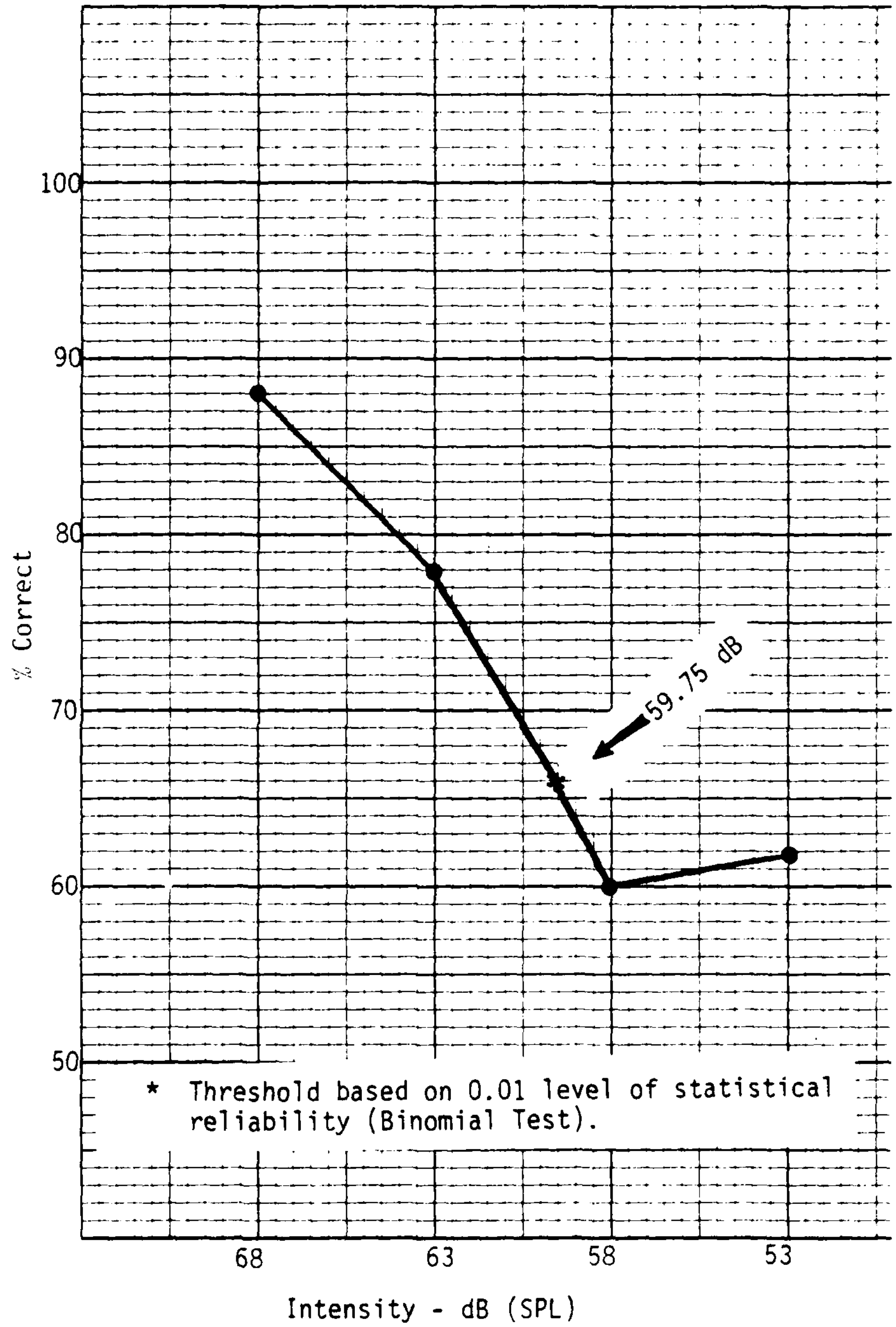


Figure B-11. Audiogram, 8 KHz: Pig 184.

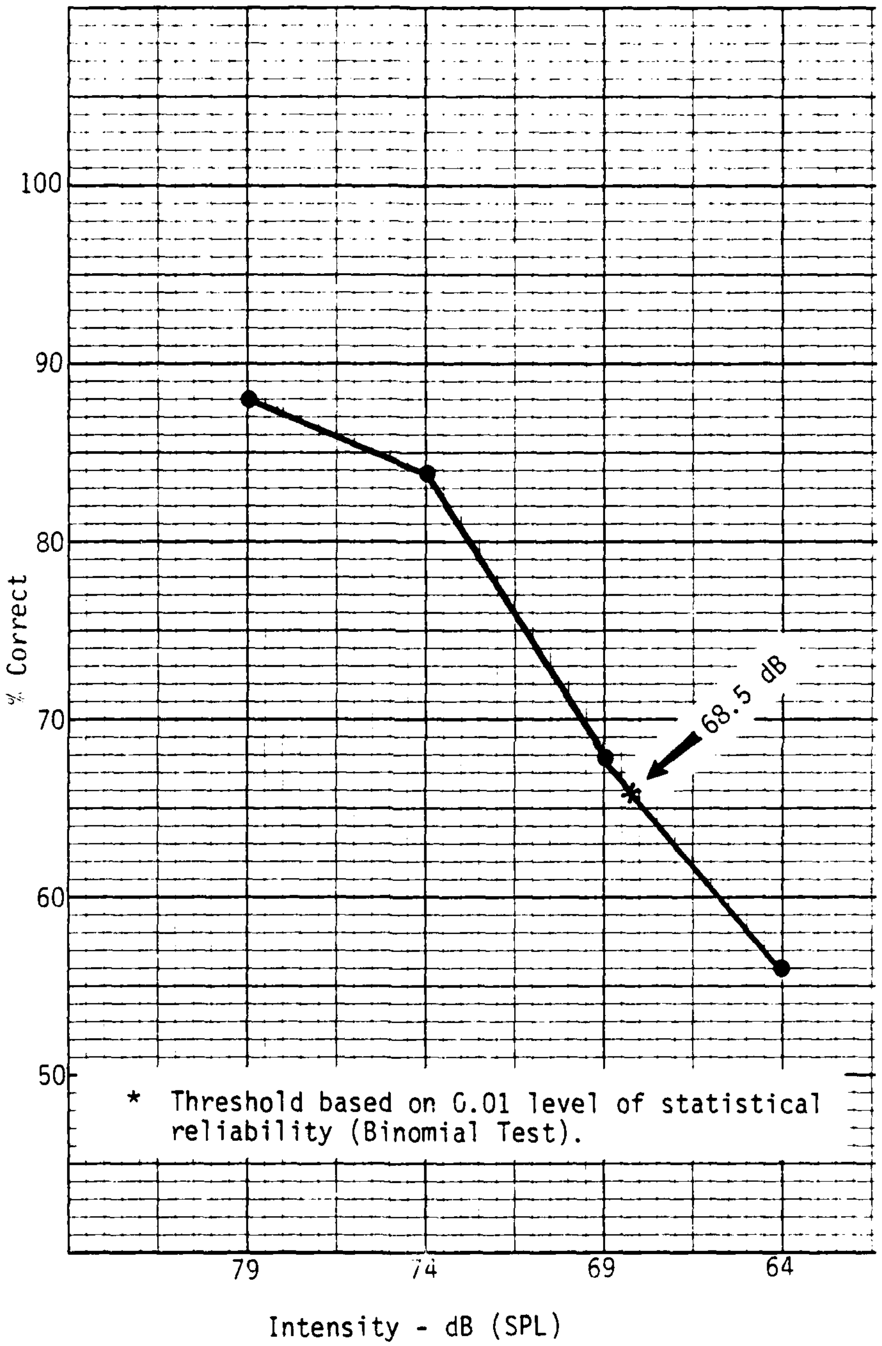


Figure B-12. Audiogram, 16 KHz: Pig 184.

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